UNITED STATES SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, **Robert Mergen, of A-4813 Altmünster, Am Wiesenhof 61, Austria, Austrian citizen,** and **Markus Manner, of A-3362 Mauer, Schmiedestrasse 1, Austria, Austria citizen,**

have invented certain new and useful improvements in

"ALUMINIUM WROUGHT ALLOY"

of which the following is a specification.

BACKGROUND OF THE INVENTION

1. Field of the invention

The invention relates to an aluminium wrought alloy with an aluminium matrix in which a soft phase and hard particles are incorporated, the soft phase being an element from a first group of elements consisting of tin, antimony, indium and bismuth and the hard particles being scandium and/or zirconium and at least one element from a second group of elements consisting of copper, manganese, cobalt, chromium, zinc, magnesium, silicon and iron, as well as scandium and/or zirconium or inter-metallic phases of scandium, zirconium with aluminium or aluminium with the elements from the second group, a base layer for a bearing element made therefrom, which can be disposed between a protective shell and a running layer of the bearing element, as well as a bearing element with a protective shell, a running layer and a base layer disposed in between.

2. The Prior Art

Alongside many other development trends in the engine-building industry today, there are two main aspects which can be singled out. First of all, engines are becoming increasingly more powerful and, secondly, these engines are becoming increasingly lightweight. The so-called “three-litre car”, which is promoted in the various media at regular intervals, is an example of this trend. These specifications pursued by the automotive industry have had a knock-on effect on the various industries supplying accessories, such as the manufacturers of bearing elements, for example. As a

result, bearings, such as plain bearings for example, have developed accordingly in recent years. The starting point was originally the single-layer bearing, from which the current multi-layer bearing was developed in order to meet the various requirements placed on such bearings, such as capacity to withstand load, lubricating capacity, etc.. This type of bearing generally consists of a protective shell (usually made of steel) designed to absorb mechanical stress, on top of which a layer of the respective bearing alloy is applied. Another thin coating, also known as an "overlay", is usually disposed on top of the bearing alloy, which may be galvanically produced, for example. This other, very thin layer normally contains a very high proportion of so-called soft phases, such as lead or tin for example, which impart to this layer an ability to adapt to and embed abraded material from the parts to be mounted, such as shafts. Due to the fine thickness of this "overlay", this layer is also mechanically capable of withstanding a sufficient degree of stress and serves as the so-called running layer. The bearing metal layer underneath ensures that the bearing also remains serviceable even if the running layer is extensively worn, for which purpose this bearing metal layer also contains an appropriate proportion of so-called soft phases. In order to prevent soft phases from migrating from the running layer into the bearing metal layer, thereby preventing a degree of brittleness that would otherwise occur, a barrier may be provided between the running and bearing metal to prevent migration, for example of tin. This diffusion barrier may be made from nickel.

It is also standard practice to apply a so-called binding film between the protective shell and the bearing metal, in order to compensate for the properties specific to the materials of the two layers with a view to obtaining sufficient cohesion of the

bearing, even when subjected to extensive stress. This binding film may be made from aluminium, for example.

A bearing of this type is known from patent specification WO 98/17833 A. This WO-A patent describes in particular an aluminium alloy for a layer, specifically for a plain bearing, which is free of silicon except for the impurities resulting from the melting process, and, in addition to tin, contains as the main alloying element, at least one element each from the group of elements consisting of lead and bismuth on the one hand and from the group consisting of magnesium and zinc on the other. The minimum proportion of tin is 16 % by weight. All the other elements in the alloy are limited to a total of at most 11 % by weight. The proportion of the respective element from the group which also contains antimony and indium in addition to lead and bismuth is between 10 % and 75 % of the maximum solubility of the respective element by reference to the total tin content.

From the background art, it has been suggested - e.g. in patent specification WO 97/22725 A - that in order to improve the tribological properties, aluminium alloys for plain bearings which contain tin as the main alloying element should contain an added hard substance selected from at least one element from the group of elements consisting of iron, manganese, nickel, chromium, cobalt, copper, platinum, magnesium and antimony in order to create inter-metallic phases, e.g. aluminides, in the boundary regions of the matrix, in which case another element from a second group of elements consisting of manganese, antimony, chromium, tungsten, niobium, vanadium, cobalt, silver, molybdenum and zirconium should be added as a

substitute for a part of at least one hard substance from the first group of elements in order to increase almost spherical or cuboid aluminides. This reduces the nicking effect of these hard particles, so that the aluminium alloy can contain a higher proportion of soft phases, which also specifically improves resistance to galling.

The properties which can be achieved from bearing metals always represent compromise solutions. On the one hand it is desirable to improve the resistance of such bearing metals or bearing metal alloys to galling by increasing soft materials such as tin or lead, as described above, but this can only be achieved at the cost of resistance to mechanical stress. In order to improve resistance to mechanical stress, it has been suggested in the prior art that silicon, amongst other materials, be added to the alloy. An alloy of this type is known from patent specification DE 197 30 549 A1. This DE-A1 patent describes an aluminium alloy containing 10 % by weight to 25 % by weight of tin as well as added copper, nickel and manganese, which can be added to the alloy respectively in a quantity of from 0.2 % by weight to 2.0 % by weight. This aluminium alloy also contains silicon in a quantity of from 0.2 % by weight to 2.0 % by weight and it is specified that the ratio of the proportion of copper as a percentage by weight to the proportion of nickel as a percentage by weight and the proportion of manganese as a percentage by weight to the proportion of silicon as a percentage by weight should be between 0.6 and 1.5. The silicon increases hardness and reduces susceptibility to corrosive wear, preventing the formation of coarse aluminium-copper-manganese phases, instead of which preferred nickel-copper-aluminides and manganese-silicon aluminides are formed. After a heat treatment at 250 °C, these aluminides are also finely distributed.

An aluminium-tin alloy containing 7 % to 20 % of tin is known from patent specification DE 43 32 433 A1. The bearing alloy additionally contains up to 4 % silicon along with other alloying elements, such as manganese, magnesium, vanadium, nickel, chromium, zirconium, copper, antimony or titanium, for example. The mechanism whereby silicon causes the matrix to harden is said to be due to the fact that it crystallises out of the aluminium matrix in the form of silicon particles, which thereby increases the strength of the bearing alloy overall. Since the silicon particles are distributed throughout the structure, only the soft aluminium matrix at the surface becomes worn, so that the surface becomes microscopically uneven. As a result, the silicon particles left behind as convex particles are capable of withstanding a high load, whilst simultaneously preserving the property of not bonding. The concave parts hold the oil so that the bearing alloys are able to withstand high load provided they have a thin film of oil and are in metal-to-metal contact. The finely distributed silicon particles fulfil another function in that they wear down minute irregularities and burrs on the co-operating shaft, thereby improving resistance to corrosive wear.

Tests have been already been conducted with transition metals, such as scandium for example, to determine whether they will produce a harder matrix when added to aluminium alloys. This was proposed in the case of cast alloys in patent specification WO 96/10099 A, where the scandium content may be between 0.01 % by weight and 10 % by weight.

Scandium has also been suggested as a means of producing a harder matrix in the case of wrought alloys (see e.g. WO 96/10099 A), which are different, and

patent specification WO 00/06787 A makes this suggestion for a bearing metal alloy, whilst patent specification WO 00/06788 A takes this same approach in the case of a binding layer. An alloy described in both of the above-mentioned documents may contain, for example, 0.15 % by weight to 1.0 % by weight of scandium, a total of 3 % by weight of one of the elements selected from manganese, copper or zirconium, a total of 4 % by weight of one of the elements selected from chromium, iron and cobalt as well as tin in a quantity of up to 6.5 % by weight. The hardening effect is based on the fact that scandium forms so-called A_3M phases with aluminium and the finely dispersed distribution of these A_3M phases imparts a high ductility to these alloys, which nevertheless exhibit no marked hardening behaviour. In spite of the fact that solidification is reduced due to the production process by heat treatments, these alloys have high values of mechanical strength. Patent specification DE 36 40 698 A1 discloses a bearing alloy with an aluminium base, which contains at least one element for the purpose of forming soft phases, selected from the group consisting of lead, tin, indium, antimony or bismuth, as well as silicon as a hard element and other reinforcing elements selected from the group consisting of copper, chromium, magnesium, manganese, nickel, zinc and iron, as well as refining elements from the group consisting of titanium, boron, zirconium, vanadium, gallium, scandium, yttrium and elements selected from the rare earths with atomic numbers 57 to 71.

Patent specification DE 43 19 867 A discloses a multi-layer plain bearing, which, in addition to a protective shell of steel and an overlay containing polytetrafluoroethylene, contains 5 % by volume to 30 % by volume of a metal filler and 5 % by volume to 40 % by volume of polyvinylidene fluoride, and has a bearing

layer of bronze, such as a tin bronze or tin-lead bronze, disposed in between.

A comparable multi-layer bearing is known from patent specification EP 0 005 560 A, onto the metal support layer of which a porous base layer is sintered, containing 5 % by weight to 25 % by weight of lead, 5 % by weight to 15 % by weight of tin, the rest being copper, with polytetrafluoroethylene in turn deposited in the pores of the base layer.

SUMMARY OF THE INVENTION

The objective of the invention is to propose a multi-layer plain bearing of simplified structure and at least the same durable, tribological properties as conventional multi-layer plain bearings.

This objective is achieved by the invention, in each case independently, by means of an aluminium alloy of the type outlined above, in which the element(s) of the first group of elements is (are) used in a total quantity of 4.5 % by weight maximum, the element (s) of the second group of elements is (are) used in a total quantity of 8.5 % by weight maximum, preferably 3.5 % by weight, scandium and zirconium are present in a total quantity of 0.8 % by weight maximum and the rest is aluminium and the usual impurities formed during melting, and by a base layer made therefrom and a bearing element incorporating a base layer made from an aluminium alloy proposed by the invention. The resultant advantage is that the composition of the aluminium alloy proposed by the invention is such that the overlay can be applied

directly onto the base layer, which is disposed on the protective shell, which is made from steel for example, which means that the conventionally used binding layer and the nickel barrier can be dispensed with. The composition also obviates the need for the lead bronzes used as standard in high-performance bearings, enabling the use of materials and metals which are as far as possible harmless in terms of their toxicity and suitability for recycling. In particular, the use of lead alloys can be dispensed with. The strength and in particular the dynamic strength of the resultant bond can be produced to higher values than is currently possible with standard three-layer bearings and using conventional steel/AlZn4,5 bonding. The tribological properties are also comparable with those of AlSn6CuNi. A further advantage is the high resistance to corrosion in contact with heavy oil and during use in gas-powered engines as well as resistance to cavitation as compared with AlZn4,5. The bond with steel can be produced without the need for an adhesion-imparting intermediate layer. The base layer may also be used for sputter bearings. Yet another advantage is the fact that the cost of manufacturing these types of bearing elements is comparable with that of existing standard multi-layer bearings of the same quality. The aluminium alloy proposed by the invention has the requisite resistance to galling due to its capacity for plastic deformation, enabling it to adapt to geometric faults and variations, i.e. even if faults occur in the overlay due to stress, the bearing element will still continue to be serviceable. An appropriate matrix toughness is obtained by means of the A_3M phases of scandium and zirconium with aluminium known from the prior art.

These properties are further improved due to the fact that the proportion of soft phase in the aluminium alloy is at least 0.1 % by weight and the proportion of the

element(s) from the second group of elements represent(s) at least a total of 0.1 % by weight, and the proportion of scandium and zirconium totals at least 0.05 % by weight, in particular 0.1 % by weight, whilst the proportion of zirconium is in the range of between 0.01 % by weight and 0.5 % by weight, in particular in the range of between 0.05 % by weight and 0.23 % by weight, and the proportion of scandium is between 0.05 % by weight and 0.5 % by weight, in particular in the range of from 0.05 % by weight to 0.25 % by weight.

In one advantageous embodiment of the bearing element, the base layer is disposed directly on the protective shell, which simplifies the structure accordingly.

It is also possible to use an alloy with a base of lead, tin, bismuth, indium or copper for the overlay or the overlay may be a layer of plastic, in particular selected from a group consisting of polyamide 6, polyamide 66, POM, silicone, PEK, PI, TPI, PEEK, PPS, PVDF, PTFE, as well as mixtures thereof, enabling the aluminium alloy proposed by the invention and the bearing element containing it to be adapted to a whole range of different applications.

It is of particular advantage if the layer of plastic contains a solid lubricant, such as MoS_2, graphite or similar for example, in which case the bearing properties of this plastic layer will be further enhanced, enabling the bearing element to be used without any or with only the smallest quantities of lubricant, such as a lubricating oil or lubricating grease, for example.

Finally, the overlay may also be provided in the form of a lubricating varnish.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to provide a clearer understanding, the invention will be described in more detail below with reference to examples illustrated in the appended drawings. Of the simplified schematic diagrams:

Fig. 1 illustrates a bearing element in the form of a plain bearing half-shell;

Fig. 2 is a table setting out various aluminium alloys proposed by the invention;

Fig. 3 plots a comparison of tension-elongation values for various aluminium alloys.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Firstly, it should be pointed out that the same parts described in the different embodiments are denoted by the same reference numbers and the same

component names and the disclosures made throughout the description can be transposed in terms of meaning to same parts bearing the same reference numbers or same component names. Furthermore, the positions chosen for the purposes of the description, such as top, bottom, side, etc,. relate to the drawing specifically being described and can be transposed in terms of meaning to a new position when another position is being described. Individual features or combinations of features from the different embodiments illustrated and described may be construed as independent inventive solutions or solutions proposed by the invention in their own right.

Fig. 1 illustrates a bearing element 1 proposed by the invention in the form of a plain bearing half-shell.

It should be pointed out at this stage, that the invention is not restricted to bearing elements 1 in the form of plain bearing half-shells and may also be used for other bearing elements 1 of the type made from aluminium alloy, such as thrust rings, for example. Moreover, bearing elements can be produced not only as half-shells but also as full shells.

The bearing element 1 illustrated in Fig. 1 is made up of a protective shell 2, a base layer 3 proposed by the invention and a running layer 4. The protective shell 2 is usually made from steel, but may naturally also be made from other similar materials which fulfil the same or a similar function, that is to say will provide the mechanical strength required of the bearing element 1. The mechanical strength of the bearing element 1 as a whole will depend on the respective application for which it will

be used, and, this being the case, a whole variety of copper alloys may be used, such as brass, bronzes, for example. The protective shell 2 also imparts a certain degree of dimensional stability.

The base layer 3 is made from the aluminium alloy proposed by the invention. It consists of an aluminium matrix incorporating at least one soft phase as well as hard particles. The at least one soft phase is at least one element selected from a group of elements consisting of tin, antimony, indium and bismuth. The hard particles are at least one element selected from a second group of elements consisting of copper, manganese, cobalt, chromium and iron or the elements scandium and/or zirconium. These hard particles might also be provided in the form of inter-metallic phases comprising the latter elements or the elements from the second group of elements with aluminium or inter-metallic phases comprising said elements.

The soft phases on the one hand impart to the base layer 3 the capacity to form a strong enough bond with the running layer 4 disposed on top and on the other hand impart the requisite galling resistance to the bearing element 1 if faults occur in the running layer 4 whilst the bearing element 1 is in operation, thereby enabling the base layer 3 to come into almost direct contact with a component to be supported, such as a shaft, for example. The bearing element 1 is also rendered capable of embedding any hard particles which emerge due to wear when the bearing element 1 is in service. The hard particles impart the requisite mechanical strength to the aluminium alloy.

Suitable alloys for the running layer 4 are those with a base of tin,

bismuth, indium or aluminium and optionally with a lead base or an alloy with a base of CuPb and a high lead content. Tin alloys with a high content of tin offer particular advantages.

Bearing metals with a lead base which might be used include, for example, PbSb10Sn6, PbSb15Sn10, PbSb15SnAs, PbSb14Sn9CuAs, PbSn10Cu2, PbSn18Cu2, PbSn10TiO2, PbSn9Cd, PbSn10.

Bearing metals with a tin base include SnSb8Cu4 and SnSb12Cu6Pb, for example .

The running layer 4, on the other hand, may also be made from a coating of plastic. Particularly advantageous examples are polyamide 6, polyamide 66, polyoxymethylene (POM), various silicones, polyaryl ether ketone (PEK), polyimide (PI), TPI, polyaryl ether ether ketone (PEEK), polyphenylene sulphide (PPS), polyvinylidene difluoride (PVDF), polytetrafluoroethylene (PTFE) and various mixtures thereof.

If the sliding capacity of the plastic alone is not good enough, it is of advantage to add solid lubricants, such as molybdenum disulphide (MoS_2), graphite or similar, to the various plastics. Quantities of various silicones may also be added.

Other additives may also be used in order to increase the mechanical strength of the plastic layer, such as fibre matrices, such as aramide fibres, for example,

or hard substances such as carbides, oxides, nitrides, for example.

The plastic layer may also be provided in the form of a so-called lubricating varnish.

Said plastics enable running layers 4 with good sliding and anti-galling properties to be obtained, which may also be used dry. They are distinctive due to their low maintenance requirements. It is possible to operate with only a small quantity of lubricant or no lubricant at all. Water may optionally be used for lubricating purposes, which is of particular advantage if the bearing element 1 proposed by the invention is used for pumps, for example. Apart from offering a corresponding weight reduction, susceptibility to nicking has also been found to be low.

In addition to the application described here, the bearing element 1 proposed by the invention may also be used for a whole range of other applications and in particular can be used as a plain bearing or as a thrust ring in the automotive industry.

For the purposes of the invention, the aluminium alloy proposed by the invention contains the element(s) from the first element group in a quantity totalling a maximum of 4.5 % by weight, the element(s) from the second group of elements in a maximum quantity of 3.5 % by weight, scandium and zirconium in a total quantity of. 0.8 % by weight maximum, the rest being aluminium and the usual impurities resulting from the melt. It is of advantage if the proportion of soft phase, in other words the elements from the first group of elements, represent at least 0.1 % by weight. Similarly,

it has been found to be of advantage if the proportion of the element(s) from the second group of elements represent(s) a total of at least 0.1 % by weight. It is also of advantage if the proportion of scandium and zirconium also represents a total of at least 0.1 % by weight. The proportion of zirconium may be in the range of between 0.05 % by weight and 0.5 % by weight, in particular in the range of between 0.05 % by weight and 0.23 % by weight, and the proportion of scandium may be between 0.05 % by weight and 0.5 % by weight, in particular in the range of between 0.05 % by weight and 0.25 % by weight.

Said figures given for the specified ranges should be understood as meaning lower and upper limits of the respective ranges, which also includes the respective peripheral ranges of 0.23 % by weight to 0.5 % by weight for zirconium and 0.25 % by weight to 0.5 % by weight for scandium.

Copper is absorbed in the aluminium as a solid solution, resulting in aluminium-rich mixed crystals, producing hardenable composite alloys, which are deformable and readily lend themselves to rolling. Copper also has the effect of strengthening the matrix due to the hardening of the mixed crystals, whereby Al_2Cu and Al_3Zr are formed independently of one another, preferably from aluminium and zirconium, so that the resultant nucleus formation is not heterogeneous. These crystallites start to separate more or less at the same time. Using copper increases the resistance of the aluminium alloy to fatigue and also improves the resistance of the aluminium alloy to corrosion due to the corrosive effect of oil-containing substances.

In order to improve the hardness properties, it is of advantage to add iron to the aluminium alloy. As explained above, like scandium, zirconium also forms so-called Al_3M phases with aluminium, enabling solidification by means of inter-metallic hard phases. The addition of silicon can be dispensed with as a result, the advantage of which is that the nicking effect caused by higher contents of silicon can be at least alleviated or reduced. These two elements also help to produce a finer grain due to the formation of tri-aluminides.

The addition of manganese helps hardening and improves resistance to corrosion. This also enables the recrystallisation temperature to be raised. It also prevents the formation of long-spiked, brittle Al_3Fe needles, especially if the iron content is low, because iron is absorbed by the AlMn crystals which are formed by preference.

Adding cobalt and chromium can also help to harden the aluminium alloy.

The effects of the individual elements are known in principle from the prior art, for example from the documents mentioned above. Using these elements for an aluminium alloy, in particular for an aluminium wrought alloy in said range of quantities, especially for a base layer 3 disposed between the protective shell 2 and the running layer 4 and combining said properties, e.g. anti-galling properties, adhesion, anti-corrosion properties, advantageously offers the possibility of dispensing with various other layers which are provided as standard on existing multi-layer bearings,

such as barriers to prevent migration, and these effects have not been described until now.

In other embodiments of the aluminium alloy, compositions were made up as set out in table of Figure 2 and their properties measured.

It should be pointed out that the alloy compositions listed in the table should not be construed as limiting the scope of the invention as they are merely given as selected examples and the person skilled in the art will be in a position, from the teaching disclosed here, to make up other compounds within the specified limits and these compounds are not excluded from the protective scope of the patent.

In the examples listed, it was found that the mechanical properties of the aluminium alloy remain essentially constant within a specific bandwidth. By bandwidth is meant that it is possible the adapt the properties to suit a specific purpose, for example by adding one or more elements in a greater or smaller proportion. By adding a larger proportion of copper as specified in example 9, for example, higher toughness can be obtained due to mixed crystal hardening.

The toughness behaviour and the properties of the aluminium alloy generally speaking can be optimised to suit the situation in terms of cost by varying the scandium or zirconium contents.

It is also possible to optimise the properties of the aluminium alloy with

regard to the addition of the elements forming the soft phase, because mixtures adapted to the specific field of application can be produced, depending on the ductility of the element, which also have a higher mechanical strength to a certain degree, in addition to the desired anti-galling properties, albeit not to the same extent as achieved by the hard particles.

An aluminium alloy was also produced on the basis of a composition comprisingAlSn1,3Sc0,2Zr0,26Fe0,1 and its tension-elongation behaviour measured and plotted in comparison with AlSn25CuMn and AlZn4SiPb. The result is set out in Fig. 3, in which the elongation ε is plotted on the X axis and the nominal tensile stress σ_z [N/mm²] on the Y axis. The measurements were conducted on strips prepared in accordance with UN EN1002-1 using tension samples E 3 x 8 x 30 mm as specified in DIN 50 120.

As is clearly evident from Fig. 3, the aluminium alloy proposed by the invention (uppermost curve) had an elongation of 0.1 % compared with AlZn4SiPb (lowermost curve) and exhibited significantly higher values than AlSn25CuMn (middle curve) with effect from an elongation of 0.05 %. In other words, in order to obtain the same elongation, the alloy proposed by the invention must be exposed to significantly higher forces or tensions, i.e. the aluminium alloy has a correspondingly higher strength than the aluminium alloys with which it was compared.

At a value of 241 N/mm² compared with a value of 181 N/mm² for AlZn4SiPb, the ultimate breaking strength of the alloy proposed by the invention was

also found to be significantly higher, as was the limit of elasticity at 191 N/mm² compared with 85 N/mm² for AlZn4SiPb.

The corresponding values for AlSn25CuMn are 174 N/mm² for ultimate breaking strength and 59 N/mm² for the limit of elasticity.

In short, it can therefore be said that mechanical properties can be improved by using the aluminium alloy proposed by the invention whilst preserving at least comparable anti-galling properties, such as required of bearing elements 1, particularly for plain bearings.

The aluminium alloy and the bearing elements 1 made from it can be produced using methods known from the prior art. Pure elements or highly pure elements are used as the starting materials. The aluminium alloy can be applied to the protective shell by rolling, plating, e.g. electro-plating, for example. The running layer 4 can be disposed on this binding by said methods or alternatively by galvanic processes by spraying, etc..

Apart from rolling, the plastic layer may also be applied by spraying, dipping or by offset printing. Galvanic processes could also be used.

Although not absolutely necessary for the bearing elements 1 proposed by the invention, various auxiliary intermediate layers may naturally also be provided between the individual functional layers, depending on requirements, such as diffusion

barriers, pure aluminium layers, a nickel insulation. etc..

For the sake of good order, it should finally be pointed out that, in order to provide a clearer understanding of the structure of the bearing element 1, it and its constituent parts are illustrated to a certain extent out of proportion and/or on an enlarged scale and/or on a reduced scale.

The individual objectives achieved by the invention may be found in the descriptions.